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HUMAN RESOURCES

DESIGNING HUMAN-CENTERED SYSTEMS: CIRCA 2039 SCENARIO

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The advancement of technology has permitted the introduction of automation into a variety of military environments. Though automation offers new and increased capabilities, issues exist concerning the "operability" of systems with automation. For example, what is the appropriate operator workload associated with using automated systems? To answer such questions, a new and broad methodology is required.

The Air Force Human Resources Laboratory (AFHRL) is presently conducting research to develop such a methodology, called the Automation Impacts Research Testbed (AIRT). This report provides a futuristic vision of a mature AIRT and how it can assist the design of automated systems. In relating this vision, the report is written as a story set in the twenty-first century. The story illustrates the operability concept through characters who describe examples of good and bad operability designs. Additionally, the story includes a description of possible tools that might be used in the future to address operability concerns. The report ends by linking the scenario to the research presently being conducted at AFHRL.

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SUMMARY

Captain John Parrish is upset--his twenty-first-century space shuttle control system has twentieth-century problems. His data bases are easily erased; he can't talk directly with all his data links; and he has to type in order to complete his mission. His anger surges, then calms, as he encounters Second Lieutenant Mark Fillmore. Fillmore explains that his satellite control system doesn't have those antiquated difficulties because of AIRT, the Automation Impacts Research Testbed. When Parrish's curiosity heightens, Fillmore suggests a meeting at the Space SPO, the System Program Office that uses AIRT, for a better look at this unit capability.

Major D.T. Tooms gives a detailed explanation of AIRT and the operability concept that allows designers to predict the impacts of automation in terms of operator skills and human performance from a system perspective. The payoff of operability studies is that the system on the drawing board can be "seen" and tested before any hardware is produced, thus affording designers and users the capability to adjust the design to suit operational needs. Tooms also reminisces about AIRT, which is actually a twentieth-century concept presently under development by the Air Force Human Resources Laboratory. He wonders why it didn't catch on faster, because better and more cost-effective systems could have been built in the interim.

PREFACE

The purpose of the present report is to illustrate the concept of "operability" and why it is necessary to assess operability early in the design of systems. Determining the operability of systems is more encompassing than the valid, yet specific, sciences focused on determining button sizes or appropriate computer screen colors. Instead, it concerns the "usability" of systems in their intended operational environment, with emphasis on the operator's perspective and his/her workload, errors, and feedback.

To avoid technical formalism, this report intentionally describes this new concept of operability in an entertaining, but informative format. Set in the twenty-first century, the report is actually a story relating numerous examples of good and bad operability designs. The story also describes futuristic tools and methods that can be used to design better systems from an operability point of view. The story, in closing, ties its futuristic view into research presently being conducted at the Air Force Human Resources Laboratory under Work Unit 3017-08-06, Methodology for Evaluation of Automation Impacts on Tactical Command and Control (C2) Systems. Much of the research has been accomplished through contract with Bolt Beranek and Newman (BBN), Incorporated, under Contract Number F33615-87-C-0007.

I extend my appreciation to Dr. Richard Pew, Dr. Kevin Corker, and their staff at Bolt Beranek and Newman, Incorporated, for they have given us a glimpse to the future of system acquisition in their development of a prototype called the Automation Impacts Research Testbed, or AIRT.

I also acknowledge my senior staff officials, Colonel Harold Jensen, Colonel Donald Tetmeyer, Colonel James Clark, Mr. Bertram Cream, and Dr. Lawrence Reed. Without their support and foresight, it would not have been possible to use such an unusual, but informative format, to convey such a significant message.

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PROLOGUE

Space Platform Station 3, Orbit 3B, 24 Nov 2039. Captain John Parrish--disgruntled, tired, and frustrated--ambled slowly to the cafeteria for some Turkey Day treats. He has just spent a long shift on the Space Shuttle Mover System or SPSMS. Captain Parrish would rather call it "SPASMS." His job is to orchestrate the movement of space shuttles which routinely fly patterns as congested as Groundstation Chicago--O'Hare to the oldtimers. Instead, he spends more time wrestling the system.

"Thanksgiving," he mumbled to anyone who would listen. "Boy, would I be thankful for a system that made my job easier, not harder."

"Sir," chirped Second Lieutenant Mark Fillmore, who is wearing the distinctive space controller jump suit, "what system might that be?"

"You know, ol' SPASMS. I'm sure you have just as many problems on your control system as I do. What's your system?" chided Capt Parrish.

"Oh, I work on the Satellite Orbit Control System. You know, the new one we call 'socks'! Why don't you like SPASMS?" Fillmore inquired as he followed Parrish to a table.

ACTION

As they sat down, Capt Parrish reluctantly began his story.

"It all started this morning when I began entering my database into the system. Jeez, I'm no typist. It took almost an hour to enter all the weather, coordinate, and frequency data. Heck, by then I almost had to control on the fly because shuttles were comin' at me left and right!"

"Sir, in SOCS we don't have to type per se. We have direct data links to the appropriate agency. All we have to do is confirm the reception with one membrane panel stroke or voice command, our choice--takes about 3 minutes total."

"Oh yeah? Well, I bet you still had problems when they hooked up that new StarBIDS. You know, the space version of the old Battle Information Display System--BIDS. We had to tie it into an existing datalink and then toggle back and forth when we needed it. Sure the link worked from an engineering standpoint, but talk about confusing! Heck, I could've been talking to Mars for all I knew. They knew StarBIDS was coming, but the system was already set in concrete. I'd really like to put it in concrete!"

"Well, Sir, when we designed SOCS, we anticipated that StarBIDS was coming. In fact, we also have enough capability to handle GalBIDS and even UniBIDS. Flexibility is the key to keeping up with technology."

"Okay, I can believe that, but let me tell you this one. This morning I took a short break. I returned to my console, sat down, put on my helmet display, and promptly deleted my database. Another hour wasted--at least it was almost lunchtime when there are fewer shuttle flights."

"How did that happen, Sir?" quizzed the lieutenant.

"They, the engineers, don't tell you everything. If you take your helmet off, and then put it back on, it'll ask you the question, 'Are you ready to start?' You're supposed to say, 'Continue,' if you've taken the helmet off for only a moment. Instead, I said, 'Yes.' My database was reinitialized."

"Sir, our system has checks and balances where necessary. We made sure of that. In fact, SOCS would have asked, 'Are you sure?' Those things just don't happen on SOCS."

"How do you know that? Besides, you're only a second louie," remarked Parrish.

"A first lieutenant next month, Sir. When I got here almost 2 years ago, I got in on the tail end of helping design the system. Guys like us, controller types, we helped de-program errors and ensure flexibility."

Captain Parrish offered his experience, "Well, I'm an old hat, prior service; made technical sergeant. We sat down with engineers, too, almost 10 years ago. Boy, time flies. Anyway, we told 'em what we needed. Of course we all transferred before it was built. Never knew I would have to come back and work on this piece of...well, whatever. They did their magical programming. All I know is that what they delivered was not what we wanted back then, and it sure doesn't help us handle all the shuttle traffic now. The engineers put all their marbles with the computer, but forgot that the little guy has to use it. You guys just got lucky."

Boldly, the lieutenant disagreed, "Beg to differ, Sir. We didn't have luck; we had AIRT."

"Art? You had some Leonardo de Vinci on the design team?" quipped the captain.

"No Sir, AIRT, the Automation Impacts Research Testbed. Actually its real name is something like the Human Factors Operability Workbench. Its predecessor was A...I...R...T. We prefer to say 'Art'--a lot simpler."

Somewhat incredulous, Parrish asked, "So what is this AIRT?"

"Well, let me explain, Sir. Suppose you could sit down right now at the control panel of the Hyperspace Vehicle Remote Control Panel...."

"But that's still on the drawing board--in the conceptual phase," interrupted Parrish.

"Exactly, Sir. AIRT gives the user a 'mockup' of the system long before any hardware is manufactured. You see, back when you guys helped the designers and engineers, all you did was sit at a big table and talk." He paused and thought, "Dream is a better word." Continuing, he said, "AIRT gives you, the user, the ability to 'touch' the system and experiment in an operational context. Then you can give real feedback on what the system should do and how it sometimes keeps you from doing what you have to do."

Parrish, obviously becoming impressed, probed, "Lieutenant, that sounds like it might work. Tell me more...."

"Well, Sir, it would be a lot better if we transported over to the System Program Office. You know, Space SPO on 3A."

Space Platform Station 3, Orbit 3A, 30 Nov 39. "Hi, I'm Major D.T. Tooms. I'm glad Mark called. I can use all the operational opinions I can get!" exclaimed Major Donald Thomas Tooms, ever the salesman. Major Tooms is a human factors/operability expert who consults for the SPO on such issues.

As the three men walked down a hallway of the Space SPO, Parrish noticed that there were many computers and supporting hardware in the adjoining rooms. He wasn't familiar with all the equipment, but he did recognize the helmet displays, plasma panels, liquid crystal displays, bio-electrical interfaces, and the ever popular electronic "grease-pencil" board. In particular, Parrish was puzzled by the presence of several operational people; these were his buddies! "Funny," he thought aloud, "all I remember in the SPO was a bunch of paper-pushers."

Major Tooms responded, "We have a much more integrated approach now. Most of the people here are lab technicians working with subject-matter experts; your colleagues are helping us with a robotics-based, extra-planetary control system. However, because of technology, the operational hands are also designing components to a certain degree. Although they don't have any formal training, the operability workbench gives them the ability to influence the design. But we're getting a little ahead of ourselves.... Let's go into my office."

Maj Tooms' office lacked a conspicuous feature--a traditional, twentieth-century-style desk. Instead, Tooms had a liquid crystal table. With a laugh, he explained that his desk is "simulated" on the left half, while his real work is done on the right half.

"The right half of the LC table," he pointed out, "acts as an integrated pegboard, if you will. All the systems you saw as you were walking in are simulated and contained in my toolbox." He deftly touched an icon resembling a toolbox in the upper right of the LC table. "The box opens, almost literally, because hologram technology displays miniature items in a 3-dimensional format."

Tooms continued, "Now each of these icons represents a piece of equipment. We call them equipment 'objects.' Objects are computer code that contains attributes. Equipment objects, which represent the equipment you saw outside, consist of attributes like communication hook-ups, functions, capacity, etc. The key is that they all contain similar computer code architectures; therefore, I can take each icon and quickly connect them to create a mockup of a system. Watch."

The major moved some of the objects to fashion a small control panel. As Tooms stated, an object is simply a cluster of computer code that simulates the characteristics of a particular piece of equipment or, in other cases, a complex function or a human operator. Each object is independent; that is, objects are self-contained. But they also have a structure that allows them to easily interact with other objects. This feature permits Tooms to compose a small system in minutes.

Immediately after Tooms completed the mockup, the LC table dimmed, but highlighted compatibility checks. The major fine-tuned some of attributes of the equipment objects, and suddenly the table brightened as if to approve of the design--no more compatibility checks.

Tooms offered an explanation, "Now I have just created a quick mockup. But don't confuse this with the primitive rapid-prototyping of the last century, because this is not the last step in the process, but the first. Next I can open the human object box." It looked like a smiley face.

With ease, Tooms placed human objects with respect to nodes on the control panel. The table dimmed again, but correspondingly sent out data indicating human performance parameters. The output also indicated that there was an operability problem: a communication bottleneck.

This bottleneck was revealed by data relating to the human operator's auditory channel. Based on these performance data, the LC table displayed several solutions.

Tooms deciphered the readout, and boiled it down to two alternatives: reduce the communication or modify the operator requirement.

Tooms explained, "Well, we can't reduce the communications; so, we'll have to change the operators. We can try adding an operator." The threesome awaited the results.

"Aha," Tooms exclaimed, "can't do that. Another operability problem...our comm stations can't support an additional body...too many life support systems required and no space to put them in. Let's remove the additional operator and add a communications filter." Again they waited.

"Now, we're headed in the right direction," said Tooms. "The filter fits, but we still have to consider what communication messages are really required. Time to go see the user. After gathering data from the user, we can test the system in an operational context. From those tests we gather more human performance data in areas such as visual, cognitive, psychomotor...as well as auditory data."

"From the looks of this system," Tooms said as he pointed to the LC table, "we would probably key on the auditory data since we identified comm as a problem early in the design. I have a feeling, though, that once we subject the human operator objects to a scenario, we'll find a lot of interesting cognitive data as well. Do you get the idea? Now keep in mind this is a very rudimentary example, but you can see that by interacting with the potential operators, and by applying incremental adjustments, we can produce a rather good system. Do you realize the importance of this?"

Before Lieutenant Fillmore could answer, Capt Parrish blurted, "Why sure, nothing has actually been built! You can run all kinds of tests and configurations before spending a bunch of money on prototypes and production. That's when we usually find out that it's difficult to use the system. But by then it's too late to do anything but retrofit as best as possible. Sometimes the retrofits are worse than the original problem because we have no way of predicting their impact."

"Exactly," agreed Major Tooms. "Which leads me to my next point. With this system, we--actually a contractor usually does what I'm showing you--can go to the user and ask how he likes it. Normally changes can be roughed out in a short time. The user never loses contact with the contractor during the design process. The design process effectively ends when a much scrutinized specification is produced. Even then, with modular designs, production changes don't stop the presses like they used to in the last century. All along the user has something he can see and touch. And he knows that what's going to be built is consistent with what he needs because of the interactive process. You know, when I see a system built that doesn't take on human element and operability issues, I just wish that AIRT had come along sooner. Too often we human-factored the buttons, but not the process of using the buttons; thus, operability was ignored."

"Major Tooms, I have a question," stated Fillmore. "What exactly is this operability stuff?"

"Well, Mark, it addresses a whole range of issues that simple rapid-prototyping can't deal with alone. For instance, many older control systems cannot be expanded. Like SPASMS, the acquisition community--by which I mean the operators, the contractors, the Air Force, was aware of StarBIDS, but they designed the system to spec like they were supposed to do back then. However, before production, they didn't fully test a mockup in its intended operational environment. Clearly the StarBIDS issue would have surfaced--and in time for a solution. As it turned out,

SPASMS was built to spec; in fact, it made starlines because it was under cost, on schedule, and worked. Unfortunately, it was not designed or preliminarily operated in a context consistent with the other star systems--existing or forthcoming; so dare I say the spec was not altogether right?!"

Capt Parrish inquired, "Why did it take so long to include operability in systems?"

Tooms paused to think over his words and began, "The whole SPASMS issue is what really brought about the emergence of the operability idea. Actually, operability was thought about a long time ago in a laboratory last century--just a vision. The scientists wanted to create a technology and methodology that would allow preliminary testing of systems from a truly systems point of view. It just took a lot of wasted money, convincing, and a system like SPASMS to get the ball rolling."

Tooms continued, "Back to defining operability. I'm not specifically talking about design issues such as how fast the computer whirs, nor am I concerned about the measurements of a switch. All of these issues are valid system design considerations, but operability is concerned with the system in use. A litany of tough questions must be asked--and answered--up front."

Tooms held his left hand up and extended his index finger, indicating question number one: "What is the impact of adding automation? Sure, automation provides new and increased capability, but what about the operator? Can he use it? How many operators are needed and what will they do using the new capability?"

The next finger, "Is an operator likely to 'abuse' the system by using it as a high tech version of the old system? Better yet, can we even train the operator to use a complicated system to its fullest capability?"

On to the ring finger, "Like in SPASMS's case, can the system tie into other systems? What about the systems coming down the pike? Technology boomed at the end of the last century; so, the military rightfully took advantage of this boom. But did you know at times the Pacific forces could barely communicate and cooperate with the Atlantic forces because of the differences in command, control, and communication systems?"

Tooms paused and then held up his little finger, "What are the system bottlenecks? Indeed, a computer can simultaneously deliver 20 radio messages, but can an operator process them, as we saw in our little mockup?"

Finally, with increased animation, Tooms held up his thumb, the only remaining digit, and said, "Perhaps the most serious questions to answer concern mistakes. Do the operators consistently make the same small mistakes? More importantly, do they, or can they, make big blunders that are preventable? In most older systems, we didn't have any idea what mistakes could be made."

By now, Tooms was throwing both arms in the air, "Let me give you an example from the other guys. Remember the Chernobyl nuclear plant disaster in the 1980's?"

Tooms, seeing their acknowledgment, resumed, "It was a system error."

Back to the fingers, Tooms continued, "Mistake number one: human error. The operators insisted on ignoring warning systems, and attempted to turn off some danger indicators."

"Mistake number two: equipment error. The equipment allowed the operators to turn off warning gauges. Both add up to a system error; i.e., operability.

Perspiration seeping from his brow, Tooms no longer hinted at his sentiments and came right out with, "You know, it really bugs me that it took so long to realize the potential of the operability approach. Let me relate an analogy. From time to time in your career you'll present a briefing at a very high level, maybe to a few stars. Well, I've done it too many times to count. My time costs money, wouldn't you agree? More importantly, generals will make decisions, based on my briefings, that impact even more money. Generals also present briefings to higher levels, such as Congress."

"But let's get to my point. We all do dry-runs. Why? To ensure that our briefing will provide the correct message to an inquisitive, and perhaps hostile audience. We ensure that we can answer the tough what-if questions during dry-runs to prevent our future embarrassment by having to answer them unprepared. Underlying the well-rehearsed briefing is the assurance that our program stands on its own. Why has it taken so long to do the same thing for our human/machine programs? We need to dry-run or rehearse them before it's too late in the acquisition process. All too often we're embarrassed by the 'operational questions' asked of the human/machine system. Systems like the operability workbench give us the ability to avoid the operational embarrassments."

Almost out of breath, Tooms rhetorically asked, "And what's the real payoff? Well, designing a system that can be used from Day 1 after fielding, instead of fumbling with operational questions after it's built. We've demonstrated that we can build great control panels, exactly to specs, but can our guys effectively use them in the real universe?"

"Furthermore if we're reeeally good," Tooms emphasized, "we've looked far enough ahead so that new equipment doesn't have to be thrown aside whenever a new threat or system appears. Technology does not win wars. It's the total system, man and machine, that wins and preserves our freedom. That's what operability is all about, Gentlemen. Questions?"

Parrish almost apologetically asked, "Major Tooms, what about those ops guys outside?"

Tooms explained, "Sorry, I guess I got on my soapbox there. The guys outside are helping us tweak the systems before final production. At this point, with the techniques we have available, the operators can move the switches a bit or tune the frequencies, kind of a last-minute test drive before the assembly line is cranked up."

Parrish reiterated, "Ops guys designing systems; I love this country!"

With no other questions, both visitors--drained but satisfied--stood up, expressed their gratitude and started to exit. Lieutenant Fillmore quickly gained a lead on Captain Parrish, who was still eyeing the equipment. Major Tooms noticed his curiosity. Wanting to capitalize, Tooms beckoned, "Captain Parrish, want to make a difference in the Air Force? C'mon back. I could use a little help...."

Ever the salesman.

SUMMARY

The Air Force Human Resources Laboratory is presently researching and developing the Automation Impacts Research Testbed, or AIRT, described in the story. This research serves as the basis for attaining the "operability vision" Major Tooms referenced in his talk with Captain Parrish and Lieutenant Fillmore. It is a vision shared by Major Tooms and the Air Force Human Resources Laboratory.

The acquisition community in the Air Force would indeed benefit from a tool or methodology that allows dry-running of designs before prototyping and production. The benefits of such a tool include effectiveness and efficiency brought to human-centered systems. These properties in turn would bring lower costs and fewer retrofits.

But what should this tool consist of to satisfy the vision? Several components are required:

-- A rapid-prototyping capability
-- A suite of configurable operator-oriented objects that include visual, auditory, cognitive, and psychomotor models
-- Scenario development tools
-- Data reduction features available during simulation execution
-- Post-processing data reduction features

To complete the vision, it is necessary to combine the components above in a manner that allows flexible testing of virtually any human/machine system. Once appropriately combined, the resulting operability testbed and assessment tool would then allow rapid-prototyping of systems before the design is fixed. These quick prototypes allow designers to create a "living" specification. Such specifications shape experiments and test configurations that provide valuable system and human perfc.mance data to the designer. In turn, by using these data, as well as expert consultation from operators, the designer can respond to the needs of the operator (i.e., the user) and adjust the specifications as required.

These needs, while focused on the operator, help shape and develop a "system maturity" (i.e., operability) as they are applied in various scenarios. Scenarios exercise the test configurations and assist the designer in reaffirming the design or fostering changes. Throughout the process, the data reduction features offer a quantifiable means to assess the impact of automation, or of lack of automation. Furthermore, the operator remains a key player in assisting the process.

Once the appropriate mixture of man and machine is agreed upon by operator and designer, then the specification becomes more binding. However, at this stage, the system has already been through extensive test and evaluation before any equipment has been built. Hopefully, by using the operability approach, which depends heavily on modularity, any post-production changes are avoided. If not, the modularity promotes easier modifications without the need to completely redesign the system.

EPILOGUE

Again, as Major Tooms indicated, the payoff is a better system that is more responsive. Moreover, the system is longer lasting in the sense that it does not have to be replaced quickly to meet new threats or be compatible with forthcoming systems. This quality promotes less expense over the course of a system's acquisition and operational life. But perhaps most importantly, the operability approach and assessment of automation impacts should prevent the system from being unprepared and, thus, risking "embarrassment" from those "operational" questions.

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